

Air Quality Considerations for Biofuels: Development of preliminary estimates of permitted potential emissions for the bioenergy supply chain



Garvin Heath
Yimin Zhang
Daniel Inman

December 4, 2014

USDA Air Quality Task Force meeting
Ft. Collins, CO

Issues Addressed in This Presentation

- Biorefineries and other biofuel supply chain facilities will require air permits for construction and operation and air emissions are a sustainability issue.
- Except for very recent experience from a select number of cellulosic biorefineries, little is known about the requirements to meet regulations, what are expected air emissions from such facilities and what impact they could have on facility operations and costs.

Context and Broad Goals

Support DOE's BioEnergy Sustainability Program: NREL's sustainability analysis program aims to better understand air emissions from the biofuel supply chain, applicable regulations and implications for cost, operations and sustainability

- **Ultimate aim:** to develop tools and analyses that can assess air pollutant emissions and potential health consequences from the cellulosic biofuel supply chain at high spatial, temporal and chemical resolution and can compare results to those from incumbent systems

Address research gaps

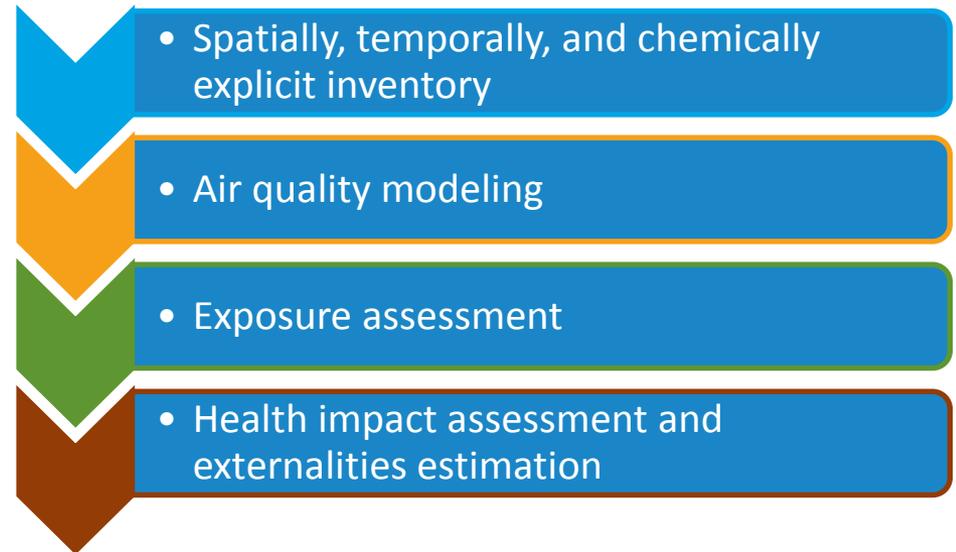
1. Lack of updated information linking DOE's stage/pathway advanced designs that enable comparison of estimated emissions to applicable regulatory limits
2. Lack of quantification of life cycle (supply chain) ozone and PM-precursor emissions from different cellulosic biofuel pathways based on DOE advanced designs
3. Lack of spatially, temporally, and chemically resolved life cycle inventories of air pollutant emissions to enable
 - a. Examination of source-level emission reduction opportunities
 - b. Comparison to existing inventories (e.g., EPA's National Emissions Inventory)
 - c. Estimation of air quality and health impacts from large-scale cellulosic biofuel production and use.

Approach

For each life cycle stage, based on inventory



For life cycle impact evaluation, considering all stages and net effects

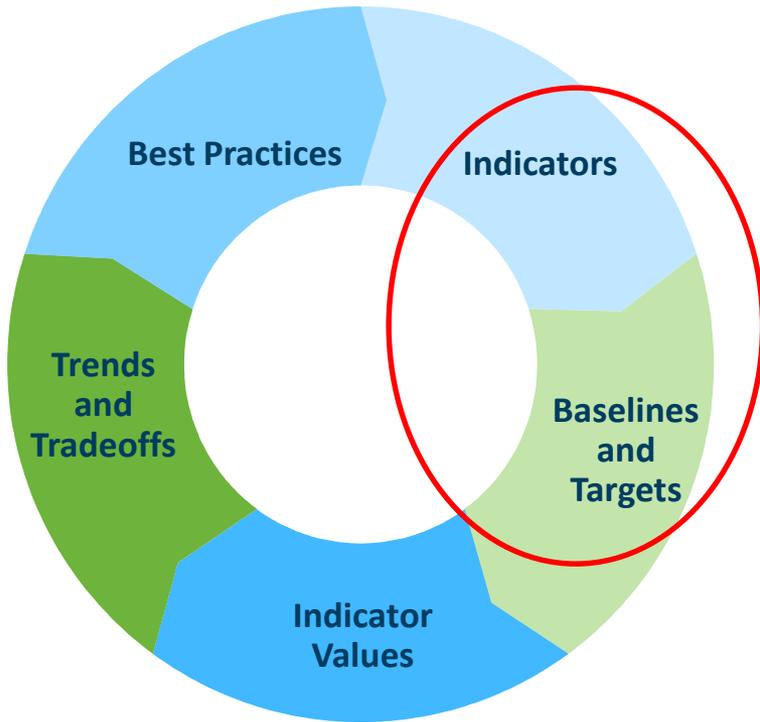


Life Cycle Stages

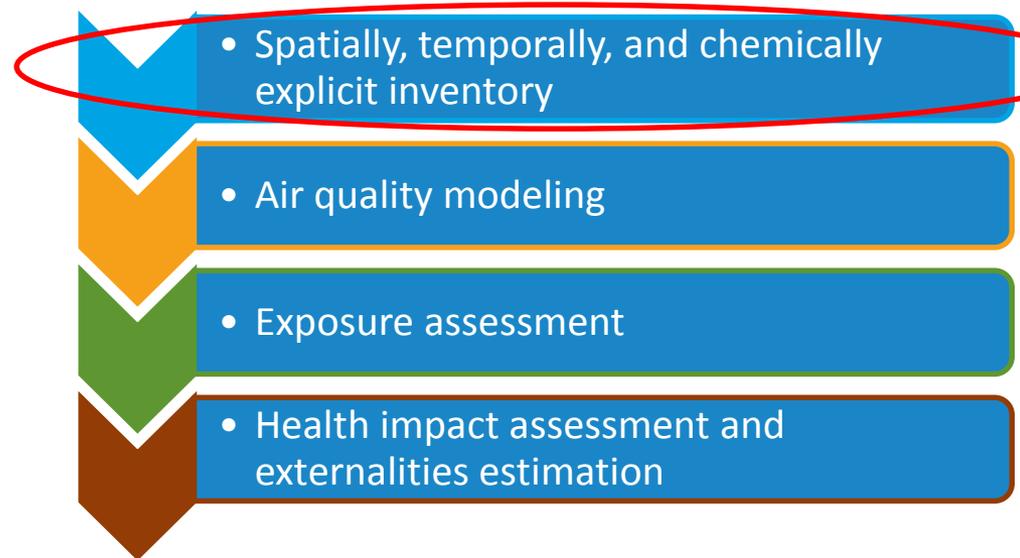


Progress

For each life cycle stage, based on inventory



For life cycle impact evaluation, considering all stages and net effects

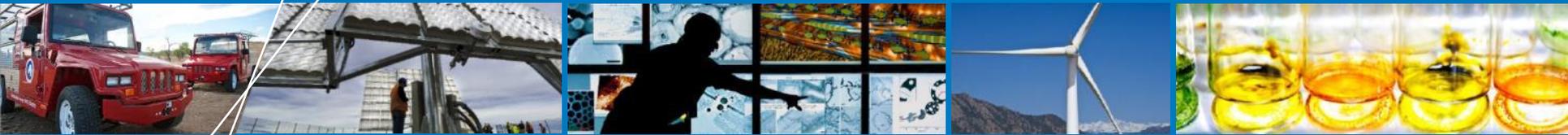


Life Cycle Stages



FY12-14

FY14-15 (regulations, PTE, controls)



Sugars-to-Hydrocarbons (HC) Biorefinery Air Emissions

Goals

- Identify air quality regulations applicable to biorefineries
 - Completed: Biological conversion of sugars-to-HCs biorefinery as per the design case described in Davis et al. (2013)
 - Next: fast pyrolysis (PNNL/NREL design: Jones et al. 2013)
- Understand potential air permitting requirements
- Quantify regulatorily-required estimates of permitted *potential* emissions (so-called “potential-to-emit” (PTE)) (*see caveats slide*)
- Provide feedback to the biorefinery design teams to incorporate emission controls if necessary

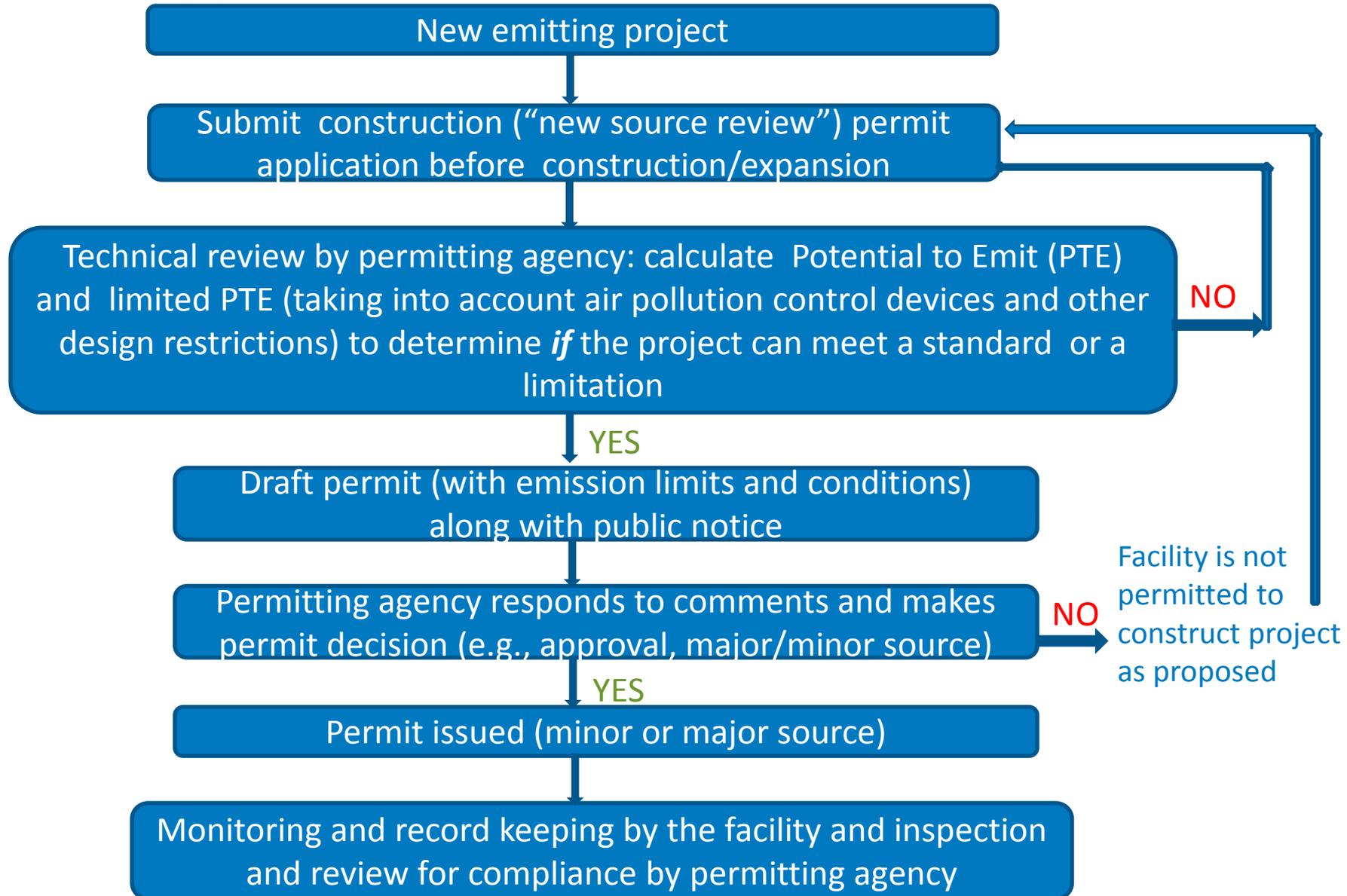
Next:

- Further investigation of strategies to reduce emissions and their potential effect on depot operation, performance and cost
- Collection of available measurements or specific models regarding emissions from depot sources to validate PTE estimates

Caveats on Preliminary Results

- Current design case (Davis et al. 2013) does ***not*** have all necessary information/data needed for making accurate emission estimates for permitting purpose – assumptions are unavoidable, and our results are ***preliminary***.
- Current sugars-to-HC conversion is not designed with the goal of optimizing air emissions.
- Emissions factors are not readily available from literature, EPA guidelines, and existing permits for some novel unit operations – e.g., boiler using a combination of biogas, sludge, lignin and other residues.
- We reviewed only federal regulations and permitting requirements; states or localities may have additional or more stringent requirements.

Overview of construction, aka new source review (NSR), permitting process



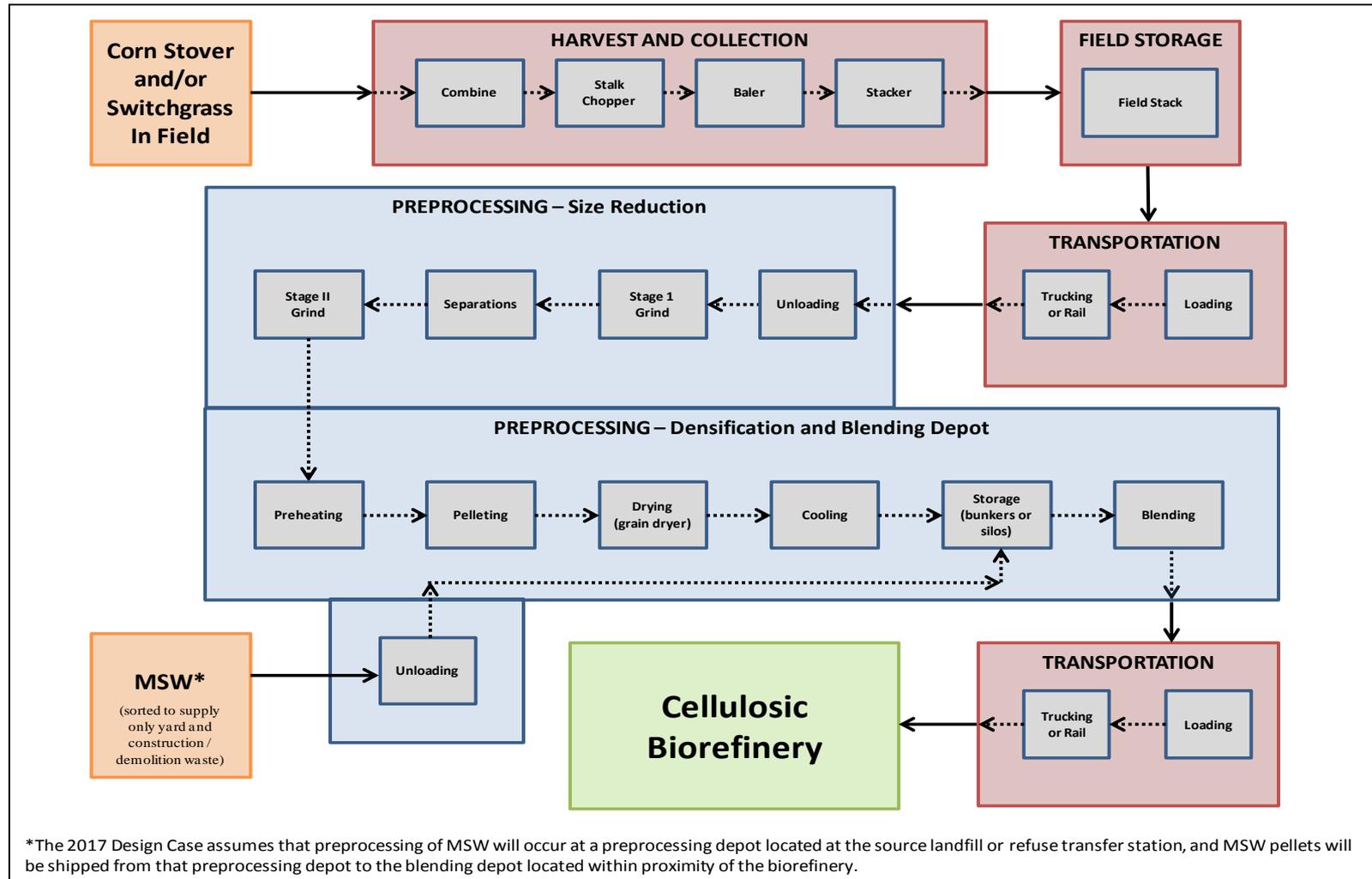
Operating permits

- In 1990, Congress established the operating permit program under Title V of the Clean Air Act Amendments.
- Consolidated all air pollutant control requirements into a single “operating permit” that covers all aspects of a source’s year to year air pollution activities.
- Who needs it?
 - Any source with a major source permit under NSR
 - Major sources for hazardous air pollutants
 - Others (e.g., solid waste incineration units, affected sources under Acid Rain Rules)

PTE and limited PTE

- **PTE: Maximum** capacity of a stationary source to emit air pollutants under its physical and operational design (e.g., 24 hours, 365 days)
→ **worst case scenario**
- **Limited or post-permit PTE:** takes into account permit limitations (e.g., conditions regarding operational limitations, use of emission control devices), which are federally enforceable.

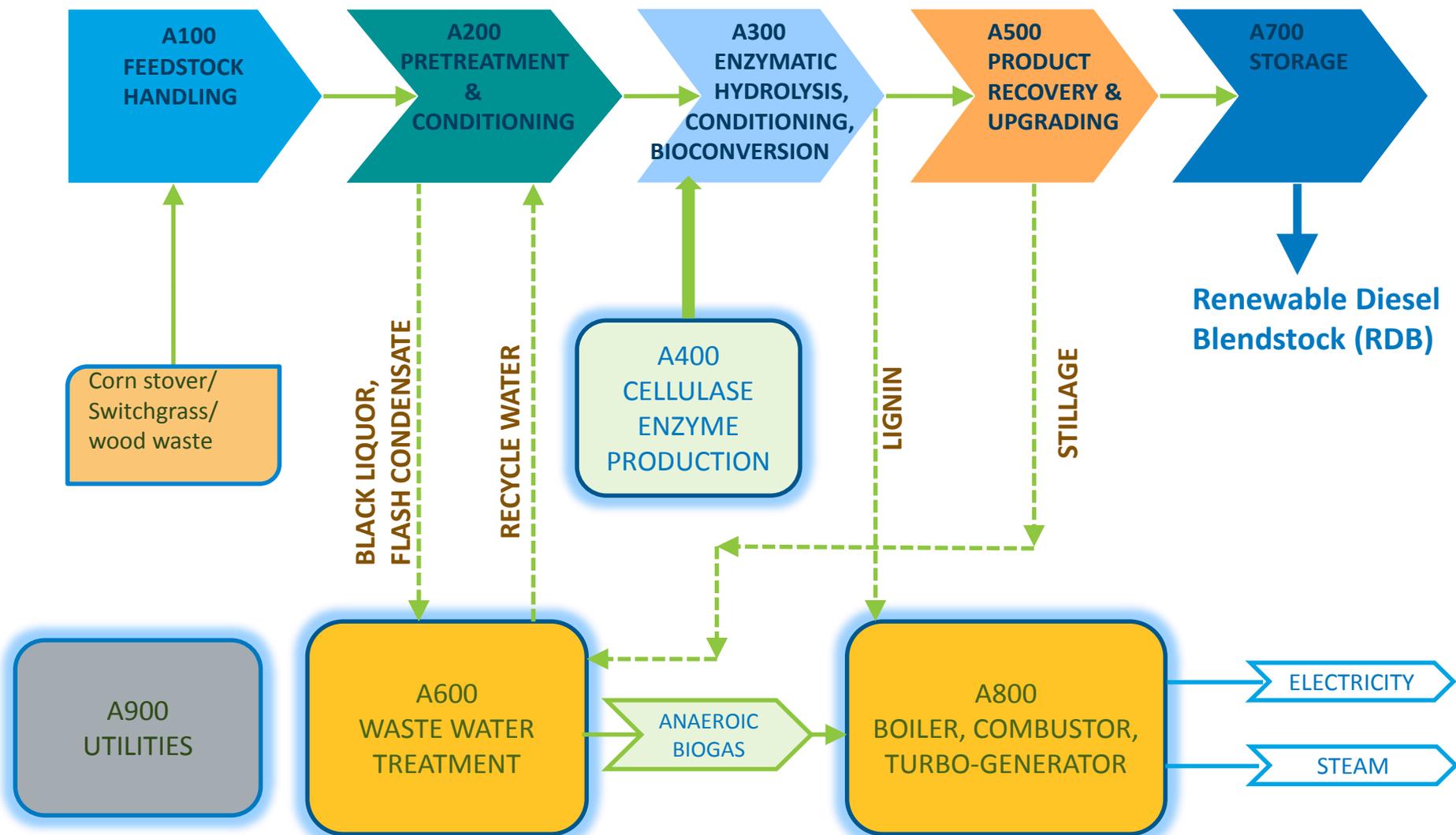
Biomass logistics systems for sugars-to-HCs



 - Feedstocks

 - System boundary of a biomass depot, where each small box represents individual operation

Simplified process flow diagram for the Sugars-to-HCs biorefinery (based on Davis et al. 2013)



Davis et al. 2013. Process design and economics for the conversion of lignocellulosic biomass to hydrocarbons: Dilute Acid and Enzymatic Deconstruction of Biomass to Sugars and Biological Conversion of Sugars to Hydrocarbons. Available at <http://www.nrel.gov/docs/fy14osti/60223.pdf>.

Equipment likely to generate air pollutants

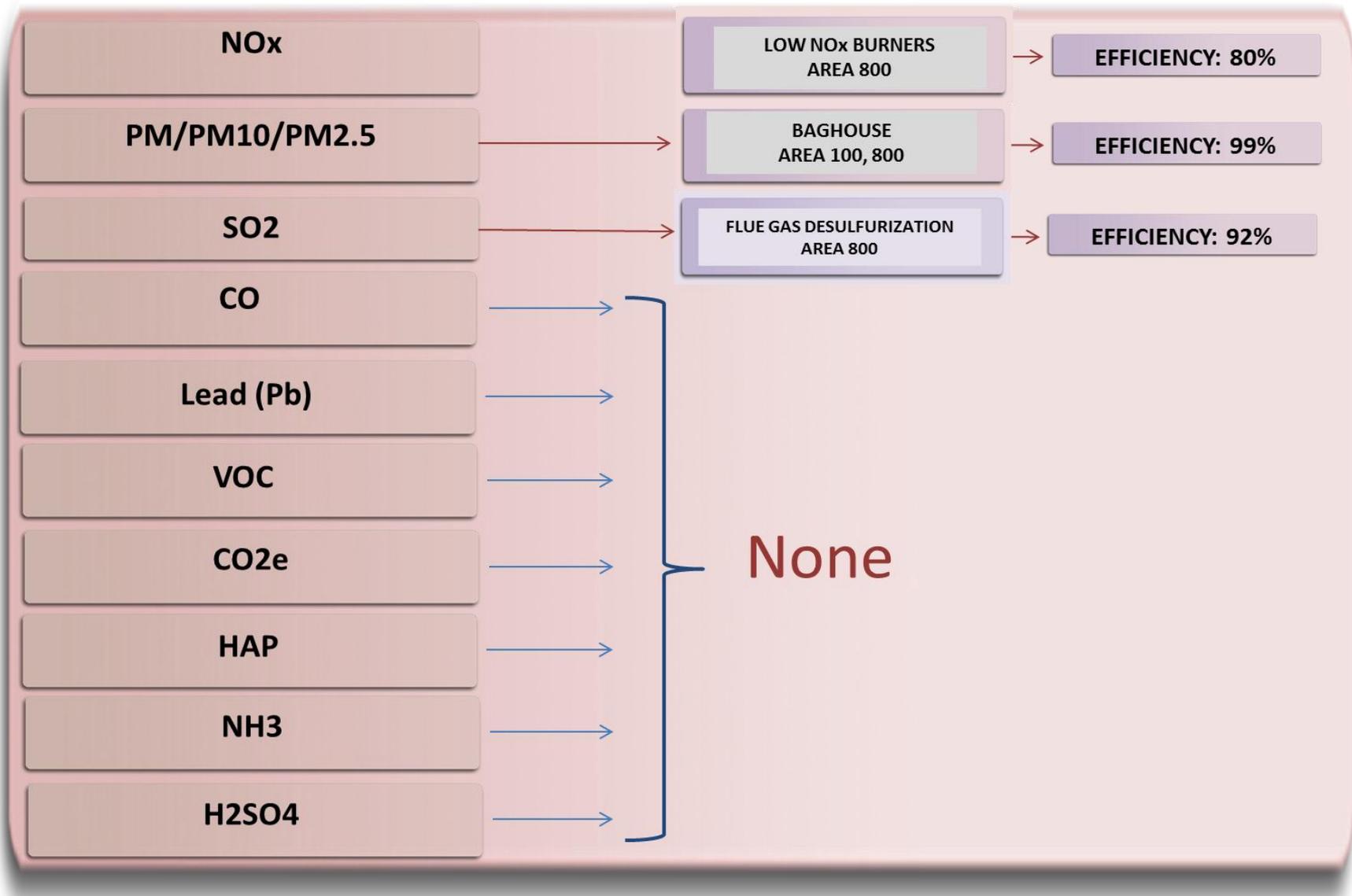
Plant Area	Equipment	Air Pollutants
Area 100: Feed handling	Dust collection systems (M-106)	PM, PM ₁₀ , PM _{2.5}
	Dust from trucks hauling feedstock, other raw materials, waste, and product	PM, PM ₁₀ , PM _{2.5}
Area 200: Pretreatment and conditioning	Presteamers (M-204) and Pretreatment Reactors (M-207)	VOC, HAP, SO ₂ , H ₂ SO ₄ mist
	Flash tank (T-204)	VOC, HAP, SO ₂ , H ₂ SO ₄ mist
	Ammonia addition tank	NH ₃
	Leaking equipment	VOC, HAP
Area 300: Enzymatic hydrolysis, hydrolysate conditioning, and bioconversion	Enzymatic hydrolysis reactors (F-300A)	VOC, HAP
	Filter press (S-205)	VOC, HAP
	Aerobic bioreactors (F-300B) and storage tank (T-306B)	CO ₂ , VOC, HAP
	Leaking equipment	VOC, HAP
Area 400: Cellulase enzyme production	Bioreactors (F-400, F-401, F-402, and F-403), and tanks (T-405, T-406, and T-410)	CO ₂ , VOC, HAP
	Leaking equipment	VOC, HAP

A technical report by Eastern Research Group

Equipment likely to generate air pollutants (cont'd)

Plant Area	Equipment	Air Pollutants
Area 500: Product recovery and upgrading	Pre-heater (no ID provided)	PM, PM ₁₀ , PM _{2.5} , NO _x , SO ₂ , CO, CO ₂ , VOC, HAP
	Hydrotreating process (S-570)	CO ₂ , VOC, HAP
	Leaking equipment	VOC, HAP
Area 600: Wastewater treatment	Anaerobic digester (T-606)	CH ₄ , CO ₂ , VOC, HAP
	Aerobic digester (T-608)	CO ₂ , VOC, HAP
	Leaking equipment	VOC, HAP
Area 700: Storage	RDB product storage tank	VOC, HAP
	Sulfuric acid tank	H ₂ SO ₄ mist, SO ₂
	Two ammonia storage tanks	NH ₃
	Loading operations	VOC, HAP
Area 800: Combustor, boiler, and turbogenerator	Boiler (M-803)	PM, PM ₁₀ , PM _{2.5} , NO _x , SO ₂ , CO, CO ₂ , VOC, HAP
Area 900: Utilities	Cooling towers	PM, PM ₁₀ , PM _{2.5} , VOC, HAP
	Fire Pump	PM, PM ₁₀ , PM _{2.5} , NO _x , SO ₂ , CO, CO ₂ , VOC, HAP
	Emergency generator	PM, PM ₁₀ , PM _{2.5} , NO _x , SO ₂ , CO, CO ₂ , VOC, HAP

Planned control devices and methods in the design biorefinery (Davis et al. 2013)

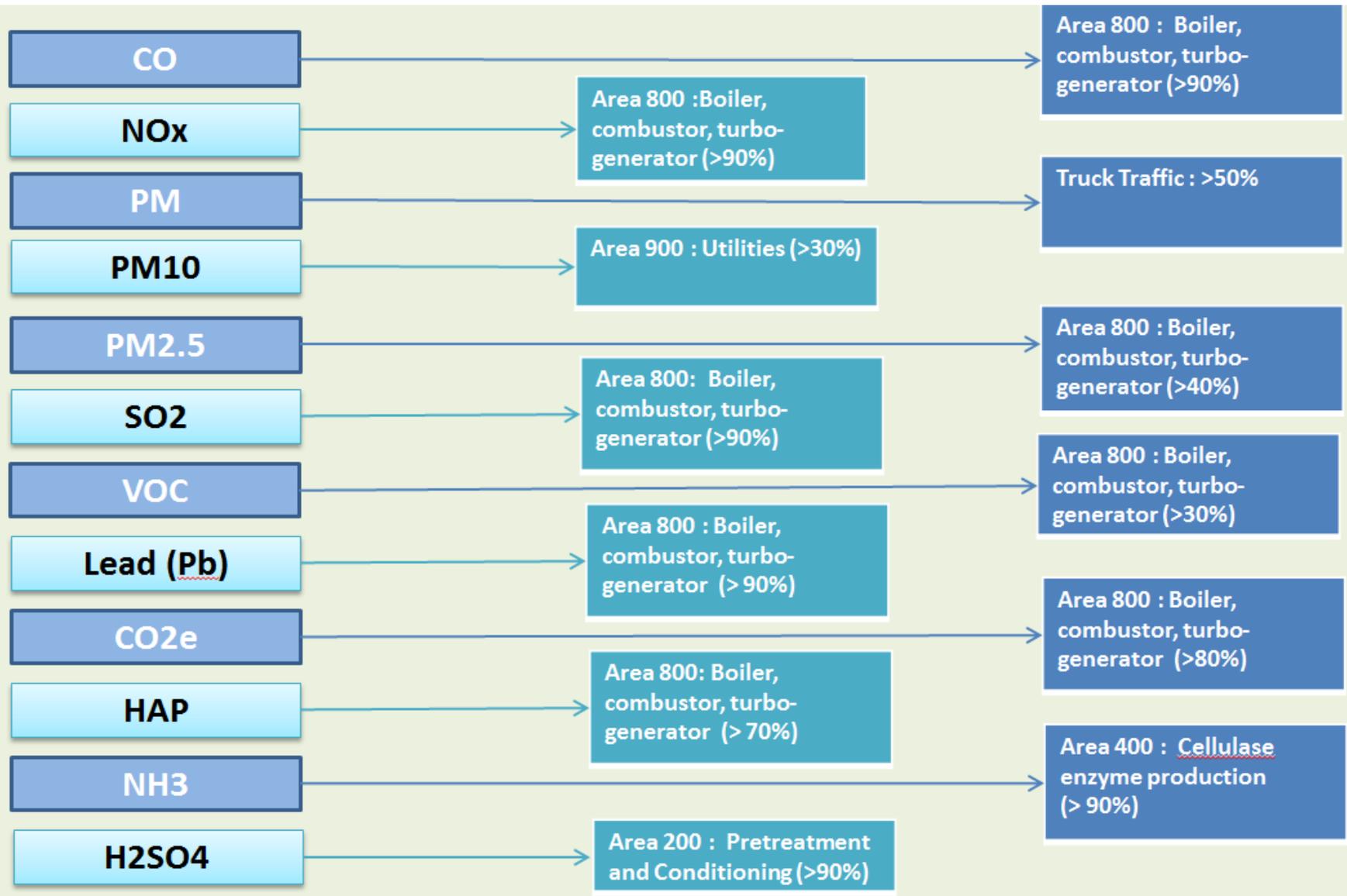


Preliminary, limited PTE estimates

Pollutant	Limited (controlled) PTE (tpy)	<u>Major source threshold (tpy)</u>
Particulate matter (PM)	96	100
Particulate matter with less than 10 micrometers in diameter (PM ₁₀)	44	100
Particulate matter with less than 2.5 micrometers in diameter (PM _{2.5})	24	100
Sulfur dioxide (SO ₂)	74	100
Nitrogen oxides (NO _x)	510	100
Carbon monoxide (CO)	1,400	100
Volatile organic compounds (VOC)	1,900	100
Lead	<1	100
GHG (CO ₂ equivalent)	1,400,000	N/A ¹
Hazardous air pollutants (HAP) (total)	390	25 (total)
Ammonia (NH ₃)	2.0	Only reporting requirement ²
Sulfuric acid (H ₂ SO ₄) mist	9.0	100

1. N/A – GHG alone cannot drive major source permitting. However, if a source is a major for non-GHG pollutant, the source will be subject to GHG PSD review if the PTE of GHG emissions exceed a certain threshold. (Some states use 0 and some states use 75,000 tpy. EPA is working on rulemaking to set this value.)
2. NH₃ is not regulated under new source review (NSR) program. If a source has a Title V permit, there is reporting requirement for NH₃.

Major emitting areas by pollutant (*preliminary*)



Key messages

1. A sugars-to-HC biorefinery as per the design case (Davis et al. 2013) will likely be subject to major source review under New Source Review and construction permit procedures, based on current design and our **preliminary** PTE estimates.
 - Our preliminary results suggest that NO_x, VOC, CO, and HAP will likely exceed the major source thresholds even if the biorefinery is located in an area in attainment of the National Ambient Air Quality Standards for ozone, and CO.
 - Further emission control technologies/devices can be employed to reduce PTE. We are in the process of investigating strategies to reduce emissions and the implications of additional emission controls on cost and performance.
2. Collocating with a biomass (preprocessing) depot could pose additional challenges to air permitting (i.e., making it harder for the biorefinery to reduce its PTE below the major source threshold). These preliminary results are for a **stand-alone** biorefinery.
3. Major source review is a greater burden of time and expense in the permitting process, and often results in the acceptance of operational limits or use of additional emission control technologies which can both impact facility economics.
4. The boiler is the single largest emitting source for CO, NO_x, PM_{2.5}, SO₂, VOC, GHG, and HAP. However, emission factors for similar facilities are not readily available. In FY15, stack test results from analogous unit operations will be collected (*if available*) to verify our estimates and we will also attempt to model combustion devices.
5. These preliminary results need to be validated once test results from newly constructed and operational cellulosic biorefineries are available.

Backup Slides

Regulated air pollutant emissions associated with sugars-to-HCs biomass depot

Activities	Air Pollutants
Haul Road	Particulate matter (PM), Particles less than 10 micrometers in diameter (PM ₁₀), Particles less than 2.5 micrometers in diameter (PM _{2.5}) (fugitive emissions)
Conveying and Handling, Truck Unloading	PM, PM ₁₀ , PM _{2.5}
Storage	PM, PM ₁₀ , PM _{2.5} (fugitive emissions)
Grinding and Separating	PM, PM ₁₀ , PM _{2.5} , Volatile organic compounds (VOC) ¹
Preheating (using frictional heat from pellet die)	PM, PM ₁₀ , PM _{2.5} , VOC ¹
Pelleting	PM, PM ₁₀ , PM _{2.5} , VOC ¹
Drying (by grain dryer using electricity)	PM, PM ₁₀ , PM _{2.5}
Cooling, Storing, and Blending	PM, PM ₁₀ , PM _{2.5} , VOC ¹ (all negligible)

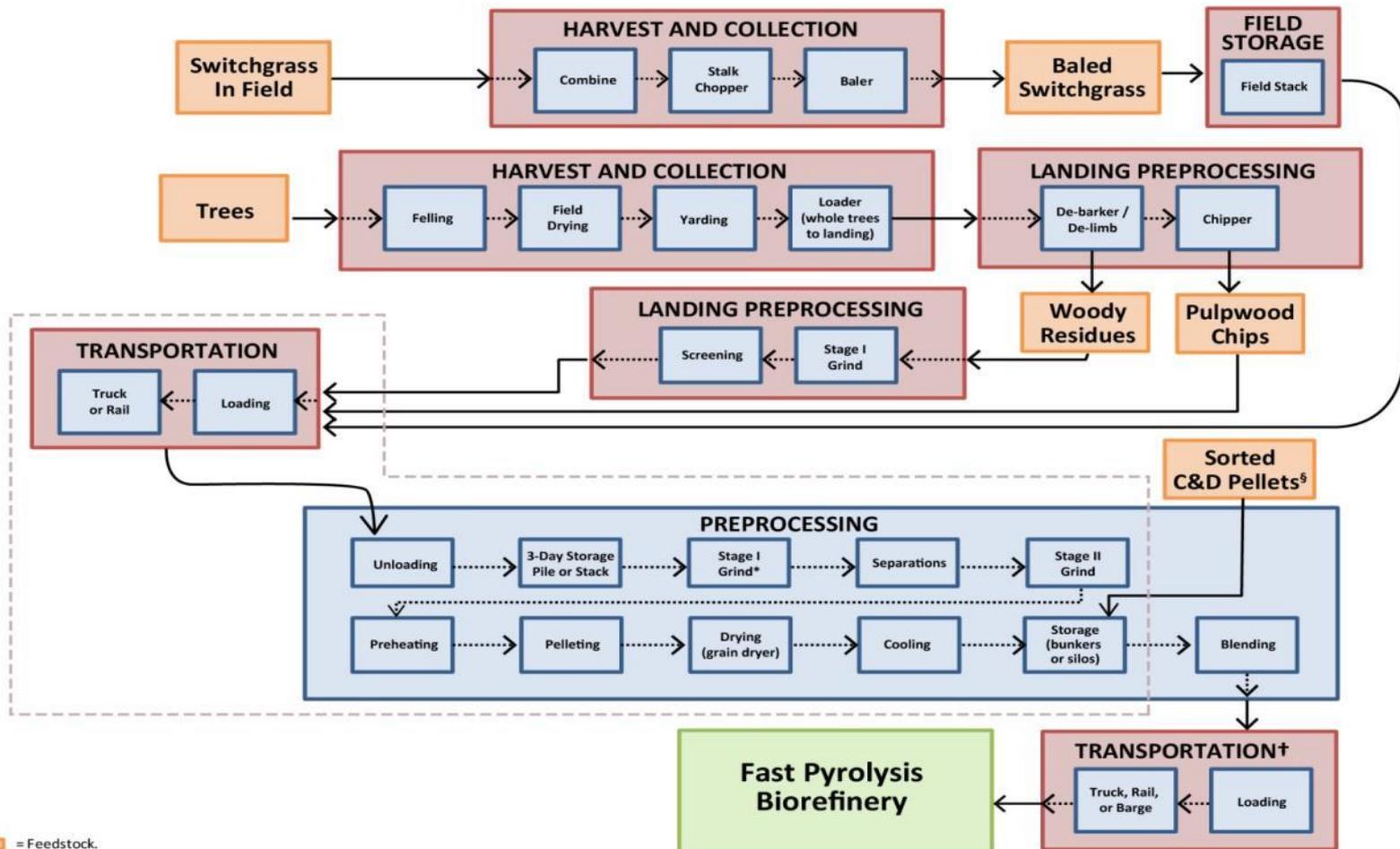
¹ VOCs are likely emitted from the operation, however, no data on VOC emissions factors can be located in our literature and permit search.

Preliminary, limited PTE of air pollutants from sugars-to-HCs depot

Pollutant	Preprocessing Design Plant Activity				Depot Collocated with Biorefinery		Depot Alone	
	Baghouse System (tpy)	Fugitive Emissions (only considered if depot collocated with biorefinery)			Limited PTE (tpy)	Major source threshold (tpy)	Limited PTE (tpy)	Major source threshold (tpy)
		Storage (tpy)	Uncaptured Emissions from Dust Collection System (tpy)	Haul Roads (tpy)				
PM	232	3	9	20	264	100	232	250
PM ₁₀	116	1	4	5	127	100	116	250
PM _{2.5}	86	0	1	1	88	100	86	250

- Assumed control efficiency of baghouse for PM, PM₁₀, and PM_{2.5} is 99%
- Assumed dust collection system will capture 95% of the exhaust from conveying and handling, pelleting, and cooling, storing, and blending
- Fugitive emissions (in grey) need to be included in PTE calculations if the depot is collocated with a biorefinery, which is considered a chemical process plant.

Biomass logistics systems for fast pyrolysis



- = Feedstock.
- = These activities are the focus of this report, and are likely to take place at a single industrial stationary source that would be required to have an air permit.
- = These activities are not expected to have air regulations, and are not considered to be the focus of this report.
- = A separate report addresses air regulatory analyses for the activities associated with the fast pyrolysis biorefinery.
- = Each feedstock undergoes these activities independently and no mixing of feedstock occurs until the preprocessing blending activity.

* Switchgrass is the only biomass type that receives stage I grind at the preprocessing facility.
[§] The 2017 Design Case assumes that preprocessing of C&D will occur at a preprocessing depot located at the source landfill or refuse transfer station (and undergo an extra washing step), and C&D pellets will be shipped from that preprocessing depot to the blending depot located within proximity of the biorefinery.
[†] These transportation activities would not be necessary in a scenario where the preprocessing activities are collocated at the fast pyrolysis biorefinery. If the preprocessing activities were collocated with the fast pyrolysis biorefinery, feedstock pellets would be conveyed (rather than transported by truck or rail) from the preprocessing activities to the fast pyrolysis biorefinery.

Regulated air pollutant emissions associated with fast pyrolysis depot

Activities	Air Pollutants
Haul Road	PM, PM ₁₀ , PM _{2.5} (fugitive emissions without emission control)
Conveying and Handling, Truck Unloading	PM, PM ₁₀ , PM _{2.5}
Storage	PM, PM ₁₀ , PM _{2.5} (fugitive emissions without emission control)
Grinding and Separating	PM, PM ₁₀ , PM _{2.5} , VOC
Preheating (using frictional heat from pellet die)	PM, PM ₁₀ , PM _{2.5} , VOC
Pelleting	PM, PM ₁₀ , PM _{2.5} , VOC
Drying (by grain dryer using electricity)	PM, PM ₁₀ , PM _{2.5}
Cooling, Storing, and Blending	PM, PM ₁₀ , PM _{2.5} , VOC (all negligible)

Preliminary, limited PTE of air pollutants from fast pyrolysis biomass depot

Pollutant	Preprocessing Design Plant Activity				Depot Collocated with Biorefinery		Depot Alone	
	Baghouse System (tpy)	Fugitive Emissions (only considered if depot collocated with biorefinery)			Limited PTE (tpy)	<u>Major source threshold</u> (tpy)	Limited PTE (tpy)	<u>Major source threshold</u> (tpy)
		Storage (tpy)	Uncaptured Emissions from Dust Collection System (tpy)	Haul Roads (tpy)				
PM	232	0	7	20	260	100	232	250
PM ₁₀	116	0	3	5	125	100	116	250
PM _{2.5}	86	0	1	1	87	100	86	250
VOC	885	46			931	100	885	250

- Assumed control efficiency of baghouse for PM, PM₁₀, and PM_{2.5} is 99%
- Assumed dust collection system will capture 95% of the exhaust from conveying and handling, pelleting, and cooling, storing, and blending
- Fugitive emissions (in grey) need to be included in PTE calculations if the depot is collocated with a biorefinery, which is considered a chemical process plant.

Key messages

1. Depots for both pathways will likely be subject to major source review under New Source Review construction permit procedures, based on current design and estimates that are preliminary.
 - This assumes agency determination that depots are collocated with the biorefinery, which is indicated in the INL designs. Collocated facilities are considered as a single source for the purpose of permitting, thus summing emissions from the depot plus the biorefinery into the same PTE for permitting.
 - The depot associated with the sugars-to-HC biorefinery may meet the major source threshold if it is not considered collocated with the biorefinery.
 - The fast pyrolysis-associated depot has (preliminary) VOC emission estimates high enough to make it a major source even without counting biorefinery emissions. But controls for VOC emissions were not considered in the current analysis.
 - This is likely true whether located in an area in attainment of the National Ambient Air Quality Standards, which have less stringent major-source thresholds (250 tpy for each criteria air pollutant), or in a non-attainment area (thresholds vary from 10 to 100 tpy)
2. Collocating with a biorefinery could pose additional challenge to air permitting (i.e., making it harder for the biorefinery to reduce its PTE below the major source threshold).
3. Major source review is a greater burden of time and expense in the permitting process, and often results in the acceptance of operational limits or use of additional emission control technologies which can both impact facility economics. Stigma can be another concern.
4. These preliminary results need to be validated once test results are available. Also, additional control strategies will be considered within our FY15 activities, for instance VOC emission controls, and their potential impact on facility operation, performance and cost.

Single source determination

- **Three-part regulatory criteria to determine whether emissions from two or more facilities should be aggregated and treated as a single source for air quality permitting purpose (for PSD and Title V permitting)**
 - 1) Source belonging to the **same** industrial grouping – have the same two-digit Stanford Industrial Classification or SIC code. However, a **support** facility is considered to be part of the same industrial grouping as that of the primary facility it supports even if the support facility has a different two-digit SIC code. Support facilities are typical those which convey, store, or otherwise assist in the production of the principal product (45 Fed. Reg. 52676, 52695. August 7, 1980).

Single source determination (cont'd)

2) Sources located on one or more contiguous or adjacent properties. The plain meaning of “contiguous” is “sharing an edge or boundary; touching; neighboring, adjacent, connecting without a break.” “Adjacent” is defined as – “close to; lying near, next to; adjoining.” Federal regulations do not define the terms of “contiguous” or “adjacent” on how distant two emission units can be and still be considered a single source.

3) Sources under the control of the same person.

- Common control can be established by ownership.
- Common control can be established if an entity has decision-making authority over the operation of a second entity through a contractual agreement or voting interest.

VOC emissions factor

- **Wood pellet emission factors developed by Georgia Department of Natural Resources for softwood**
 - **2.5 lb VOC per ton of product (hammermill)**
 - **0.5 lb VOC per ton of product (pelletization and pellet cooler)**

Source: Webinar focuses on air emissions from pelletizing wood.

<http://biomassmagazine.com/articles/10422/webinar-focuses-on-air-emissions-from-pelletizing-wood>

PSD Source Categories for Which 100 tpy Major Source Threshold is Applicable

1. Fossil fuel-fired steam electric plants of more than 250 million Btu/hr heat input
2. Coal cleaning plants (with thermal dryers)
3. Kraft pulp mills
4. Portland cement plants
5. Primary zinc smelters
6. Iron and steel mill plants
7. Primary aluminum ore reduction plants
8. Primary copper smelters
9. Municipal incinerators capable of charging more than 250 tons of refuse per day
10. Hydrofluoric acid plants
11. Sulfuric acid plants
12. Nitric acid plants
13. Petroleum refineries
14. Lime plants
15. Phosphate rock processing plants
16. Coke oven batteries
17. Sulfur recovery plants
18. Carbon black plants (furnace plants)
19. Primary lead smelters
20. Fuel conversion plants
21. Sintering plants
22. Secondary metal production plants
23. **Chemical process plants**
24. Fossil fuel boilers (or combinations thereof) totaling more than 250 million Btu/hr heat input
25. Petroleum storage and transfer units with a total storage capacity exceeding 300,000 barrels
26. Taconite ore processing plants
27. Glass fiber processing plants
28. Charcoal production plants

Regulated Air Pollutants under New Source Review Program

- particulate matter (PM)
- PM₁₀
- PM_{2.5}
- sulfur dioxide (SO₂)
- ozone (volatile organic compounds or nitrogen oxides)
- nitrogen oxides (NO_x)
- carbon monoxide (CO)
- lead (Pb)
- fluorides
- total reduced sulfur compounds (includes hydrogen sulfides)
- sulfuric acid mist
- municipal waste combustor (MWC) acid gases
- MWC metals
- MWC organics
- municipal solid waste landfill gas